TEACHING FIELDS IN INTRODUCTORY PHYSICS

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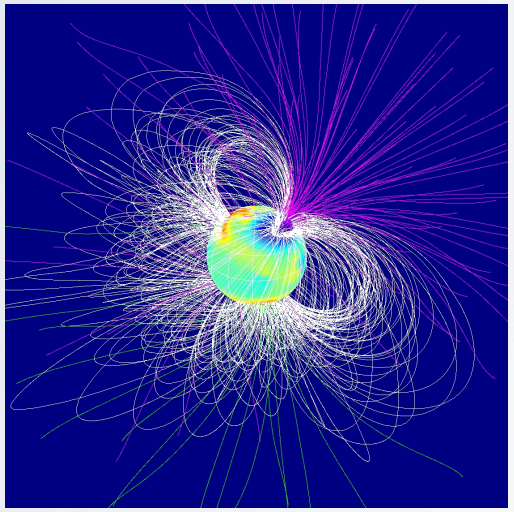
Fields

- In most areas of physics, fields are a concept of primary importance:
  - Electromagnetic fields
  - Gravitational fields
  - Temperature fields in solids
  - Pressure fields in fluids
  - Particle fields in quantum field theory
  - Tensor fields in general relativity
  - And also the basis of all waves



- And yet, no one defines what a field actually is

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How do we learn fields?

- Most physics students first encounter fields (without knowing it) in gravitation
  - *g,* often erroneously called the acceleration due to gravity, is best described as the strength of a gravitational field
- AP students run into fields again in electricity and magnetism
  - Electric and magnetic fields are often taught as “special” fields, without reference to other fields
- In upper-division physics classes, we hit temperature fields or pressure fields
  - At this point, professors usually assume you know what a field is

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Teaching fields

- Given the importance of fields in physics, it is odd that virtually no one teaches them explicitly
  - Not a difficult concept
  - Provide a good foundational understanding of basic physics
  - Make it easier to understand waves
- So we tried adding fields to our sophomore curriculum

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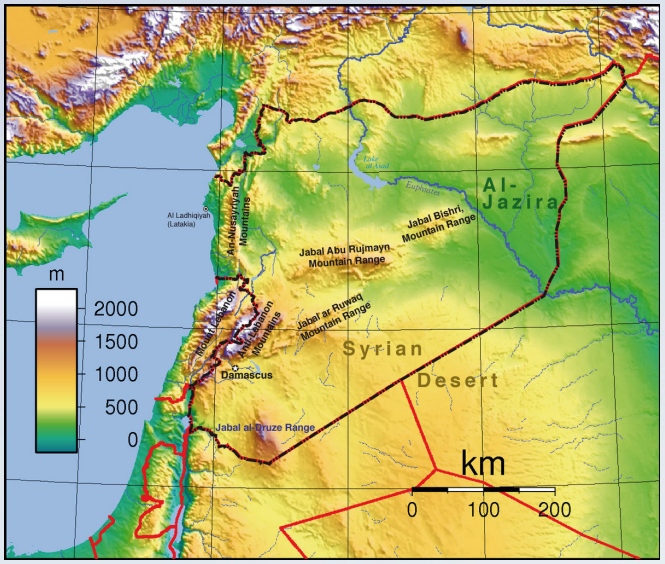
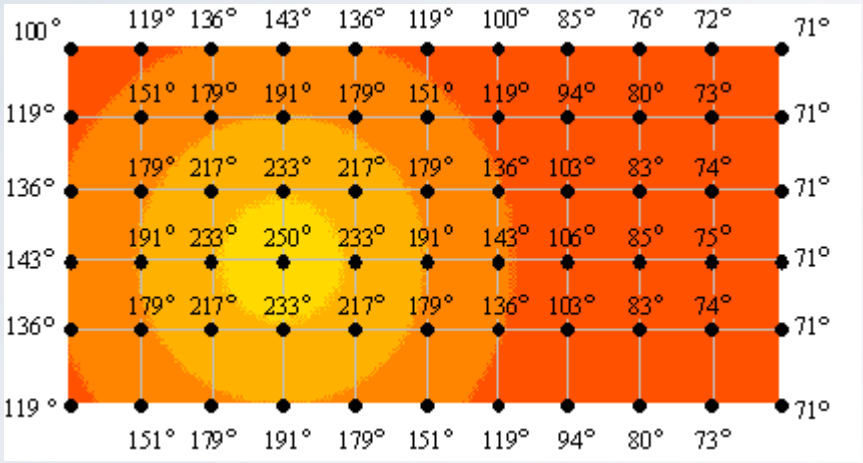
What is a field?

- Simply, a field is a set of numbers that can be assigned to different points in space
- The easiest example is usually a temperature field
- Topographical maps are also useful
- Weather maps are also good



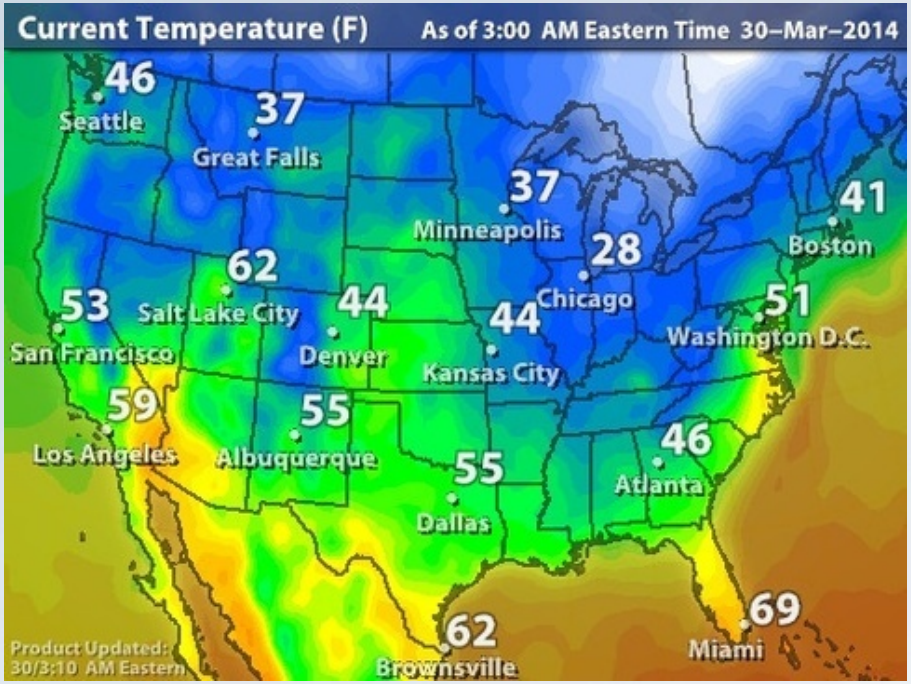


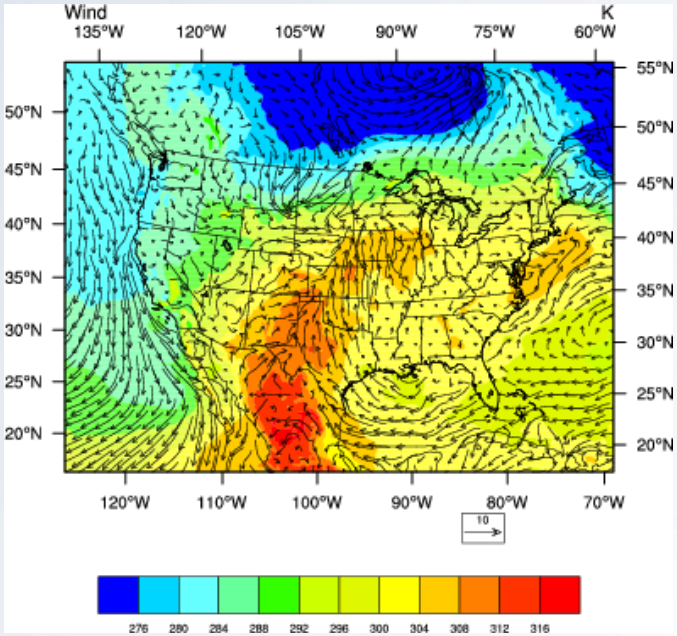
Assignment ideas

- Find examples of fields online
- Measure and graph the field of different points in the room or the school
  - Can measure just about anything – it doesn't have to be useful
- Discuss what the field is in water waves, earthquake waves, or waves moving in a slinky

Scalar and vector fields

- Scalar fields have a scalar at each point
  - E.g., temperature
- Vector fields have a vector at each point
  - E.g., wind





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Why are fields useful?

- They introduce the concept of non-local phenomena
- They allow us to visualize spatial variations in a quantity
- They let us think about how changes in one place affect other places

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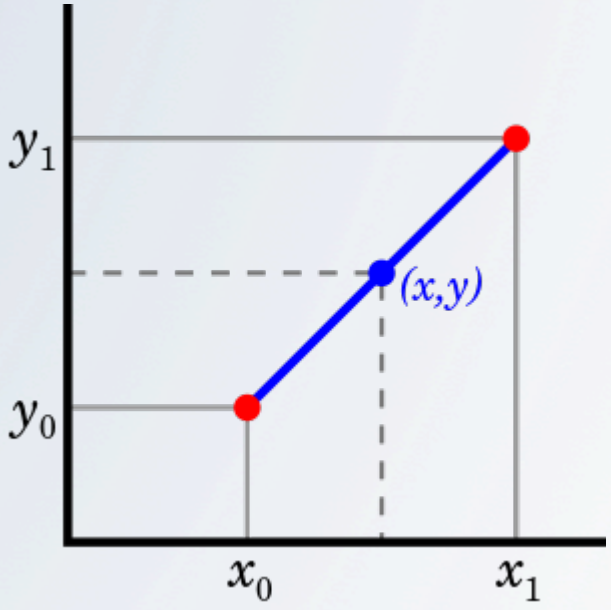
Interpolation and extrapolation

- Fields are a great place to discuss linear interpolation and extrapolation
- Also a great way to talk about the fall-off of a field
- For advanced students, the connection between geometry and the fall-off of a field away from a source could be covered



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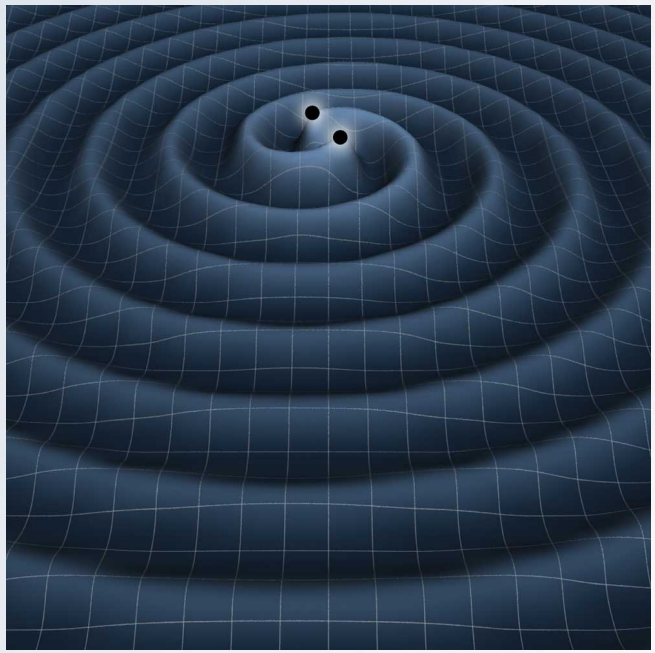
Fields and waves

- Changing a field requires the input of energy
- When one part of a field changes, it also affects the parts around it
- Thus, when you add energy to one part of a field, that energy will propagate through the field around it
- A wave is a disturbance in a field which carries energy

Why fields help with waves

- Framing waves as moving in fields, rather than a medium, avoids tricky questions
- If students understand that a field is a set of measurable numbers, not a tangible object, then waves are easy to grasp
- Students can understand not only mechanical waves but temperature waves, pressure waves…
- And later, electromagnetic waves, gravitational waves, quantum mechanical waves



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Outcomes

- The hope is that early introduction to fields will make AP Physics C concepts of gravitational and electromagnetic fields easier to grasp
- Framing waves as changing fields should make it easier to explain electromagnetic waves, without needing unsatisfying discussions about the medium of a wave
- The current program is too new to evaluate whether that has been successful
- Assessments indicate that students grasp the basic concepts without too much difficulty

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